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(56) Documents Cited
US 4157520 A US 4072918 A US 4000481 A
US 3886507 A US 3792390 A US 3091725 A

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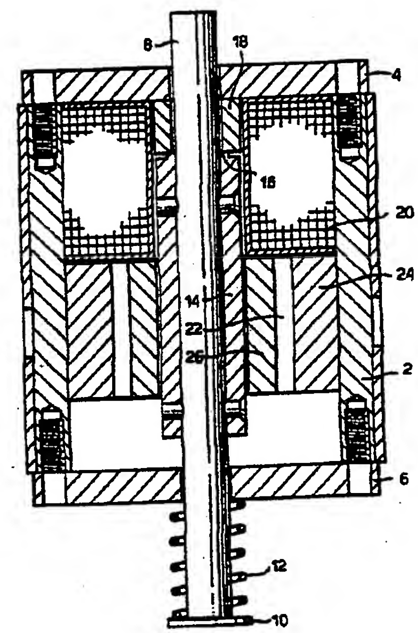
(54) Electromagnetic actuators

(57) The actuator includes a plunger rod 8 of non-magnetic material and a soft iron plunger sleeve 14. A spring 12 biases the plunger rod 8 away from a permanent magnet array 22 formed of a stack of discs. The number of discs is selected, together with the spring rate of the spring 12 and the form and winding of coil 20, to produce the required characteristics of the actuator. The plunger sleeve 14 has a stepped end face 16 serving to maximise magnetic flux by minimising gap reluctance during movement of the actuator to the closed position. Electrical actuation is effected by applying a pulse to the coil 20 to produce a magnetic flux in a direction augmenting or opposing that from the permanent magnet array 22. Manual operation of the actuator is effected by applying force to the plunger rod 18 in the appropriate direction either to overcome the magnetic flux from the permanent magnet array 22 or to overcome the spring 12.



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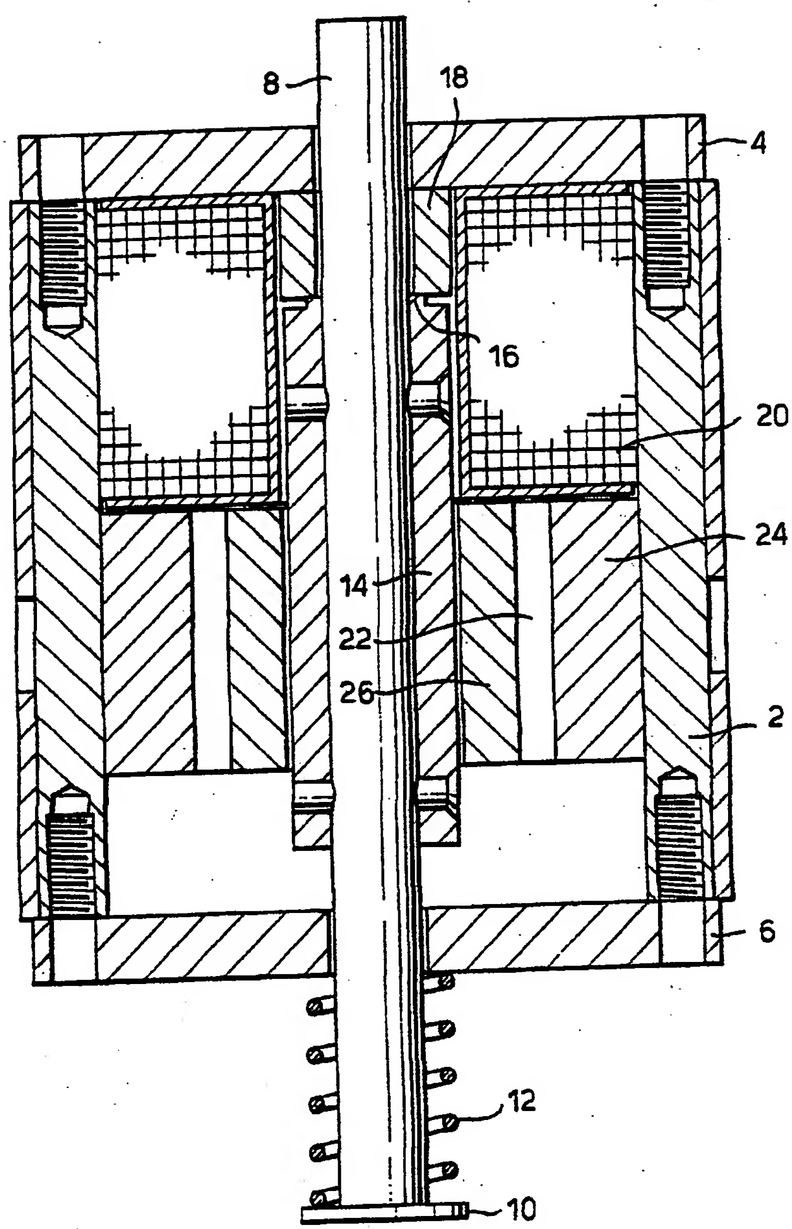
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.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DESCRIPTION

This invention relates to an electrical actuator having holding forces and operating characteristics particularly suited for use in conjunction with electrical switchgear, particularly in relation to vacuum circuit breakers, auto reclosers and contactors and for use on lower voltage air break equipment.

Hitherto, such magnetically latched actuators have utilised separate closing and opening coils. These coils produce fluxes which mostly flow in different circuits during closing or opening operation.

It is a requirement of most electrical switchgear that in the event of a loss of control power or otherwise the equipment may be opened manually to disconnect the circuit. It is generally accepted that the speed and forces developed during a manual opening should be the same or equivalent to those developed during an electrically powered or instigated opening.

According to one aspect of the invention, there is provided an electrical actuator including a plunger extending co-axially through an armature or pole piece associated with an electrical coil and a permanent magnet array axially adjacent to the electrical coil, the plunger having secured thereto a co-axial magnetisable plunger sleeve extending through the permanent magnet array and partially through the electrical coil with an end face registering with the armature and having biassing means arranged to urge the plunger axially away from the armature, first electric circuit means effective to energise the electrical coil to produce a magnetic flux augmenting a magnetic flux

arising from the permanent magnet array and opposing the biassing means to effect movement of the plunger sleeve toward the armature, second electric circuit means effective to energise the electrical coil to produce a magnetic flux opposing the magnetic flux arising from the permanent magnet array and augmenting the biassing means to effect movement of the plunger sleeve away from the armature, and electrical switch means arranged selectively to connect the electric coil to one of the first electric circuit means, the second electric circuit means and an open circuit.

Preferably, the permanent magnet array is in the form of flat rectangular cross-section block magnets.

Desirably, the plunger sleeve is of parallelepiped form.

Suitably, the end face of the plunger sleeve registering with the armature is of stepped form.

In one embodiment of the invention, as shown in the accompanying, partly diagrammatic, cross-sectional drawing, the actuator includes a cylindrical housing 2 having bolted on end covers 4 and 6 arranged co-axially of a plunger rod 8 non-magnetic material. One end of the plunger rod 8 is formed with a shoulder 10 providing a seating for a compression spring 12 bearing against an outer face of the end cover 6. The plunger rod 8 carries a soft iron plunger sleeve 14 formed with a stepped end face 16 of rectangular cross-section arranged to abut, in a closed position, a soft iron pole piece or armature 18 mounted on the end cover 4. An electrical coil 20 is positioned intermediate the

housing 2 and the armature 18 adjacent the end cover 4 and extends axially beyond the armature 18. A permanent magnet array 22 in the form of rectangular cross-section blocks is positioned intermediate the housing 2 and the plunger sleeve 14 adjacent the electrical coil 20 and spaced from the end cover 6. The magnet array 22 is secured in the housing 2 by means of a fixing plate 24 and the magnetic flux is directed toward the plunger sleeve 14 through a soft iron core piece 26.

In operation, the actuator is moved to a closed position by applying an electrical pulse to the coil 20 such that the magnetic flux produced by the coil causes the plunger sleeve 14 to move toward the armature 18, the magnetic flux produced by the coil 20 being in the same direction as, and augmenting, the flux arising from the permanent magnet array 22 to overcome the spring 12.

Soon after the plunger sleeve 14 reaches the closed position the coil electrical pulse is interrupted. However, the plunger sleeve 14 remains in the closed position since the attracting force between the plunger sleeve and the armature 18 is of sufficient magnitude as to hold the spring 12 compressed.

To move the actuator to an open position an electrical pulse is applied to the coil 20 such as to produce a magnetic flux opposing the flux arising from the permanent magnet array 22 thereby substantially reducing the net flux at the armature with a corresponding reduction in the holding force. The reduction is such that the spring force exerted by the compression spring 12 will exceed the force arising from magnetic flux and the plunger will be urged to an open

position. As the plunger sleeve 14 moves away from the armature 18 magnetic flux the flowing through the armature and the plunger sleeve spreads out or leaks. This, coupled with the increased air gap at the faces, causes a rapid reduction in the residual magnetic attraction force. The plunger 8 driven by the spring 12 thus accelerates toward the open position by virtue of the increasing net effect of the spring 12. This rapid movement induces a back electro-motive force in the coil 20, momentarily acting against any further increase in the current induced magnetic flux in the coil and acting to prevent the magnetic attraction force from re-establishing.

In a fully open position the magnetic attraction force between the plunger sleeve 14 and the armature 18 is such as to prevent the electrical pulse (if still maintained) from urging the plunger sleeve 14 toward the closed position. In addition, the effect of the magnetic force between the plunger sleeve 14 and the armature serves to increase the effectiveness of the actuator during the closing operation by restraining movement of the plunger sleeve 14 until the magnetic flux due to the coil has reached an appropriate magnitude. This magnitude is selected as to ensure that the full closing of the actuator is always achieved.

To effect manual opening of the actuator, manual force is applied to the plunger 18 sufficient to overcome the magnetic flux arising from the permanent magnet array 22 holding the plunger sleeve 14 in magnetic contact with the armature 18. As indicated, once such magnetic contact is broken the magnetic force reduces as the air gap is increased and the compression

spring 12 will act to urge the plunger to the open position.

Alternatively, to effect manual closure of the actuator, manual force is applied to the plunger 18 sufficient to overcome the effect of the compression spring 12. As the air gap is thereby reduced, so the effect of the magnetic flux produced by the permanent magnet array 22 will be increased up to a maximum upon the plunger sleeve 14 making magnetic contact with the armature 18.

In order to embrace a range of actuation force requirements, the permanent magnetic is composed of a stack of discs, of some seven millimetre thickness sheet, of a material such as isotropic neodymium ferro boron, bolted together. By varying the thickness of the blocks, so the magnetic flux arising is varied. The spring rate of the compression spring 12 and the form and winding of the electrical coil 20 are selected to produce the required characteristics for the actuator.

Isotropic neodymium ferro boron magnets exhibit a relatively high resistance to demagnetisation, that is, a high intrinsic coercivity, and are thus virtually unaffected by the opposing magnetic flux produced by the coil 20 during movement of the actuator to the open position.

In addition, the utilisation of magnets in the form of flat blocks gives rise to a permanent magnet array 22 of relatively large surface area, giving efficient magnetic coupling across the plunger sleeve 14 and the air gap.

This allows for the use of relatively thin magnetic material of comparatively low remanence and coercivity whilst minimising the reluctance of the electrical circuit providing the electrical pulse to the actuator.

The plunger sleeve 14 is of parallelepiped form giving a cross-sectional external perimeter as large as possible for a required cross-sectional area and thereby achieving a high leakage flux even at small gaps. The stepped end face 16 of the plunger sleeve serves to maximize magnetic flux by minimizing gap reluctance during movement of the actuator to the closed position. The stepped end face 16 also gives rise to a rapid reduction in the magnetic attraction force during initial movement of the plunger sleeve to the open position since the magnetic flux is only concentrated whilst the faces actually make contact.

Since, in the closed position of the actuator a relatively low reluctance path is offered to the magnetic flux in the magnetic circuit, movement of the actuator to the open position upon appropriate energisation of the coil 20 is effected relatively rapidly, an important consideration where the actuator is used in conjunction with a protective circuit. In addition, actuation with such an arrangement is achieved with tripping pulses of a magnitude of only a few amps (say three amps) although, of course, higher electrical current pulses equally also effect actuation.

Actuators of conventional design, having two coils, one to effect movement to an open position, the other to effect movement to a closed position require provision for the electrical pulse achieving opening movement to

have an electrical current value of up to approximately half the value of the electrical current required to effect movement of the actuator to a closed position. In the present arrangement, initiation of movement to the open position is achieved with an electrical current of approximately only one tenth of the electrical current required to effect movement of the actuator to the closed position.

The present invention, by utilising but a single electrical coil rather than the two coils of conventional designs gives rise to an actuator exhibiting economy in cost and space as well as a reduction in complexity in design and operation. In a conventional design of magnetic actuator having two coils, it is found that, upon applying an electrical pulse to one of the coils, a current tends to be induced in the other of the coils tending to produce a magnetic flux in opposition to the flux produced in the first coil, leading to complex designs. In actuators in which the electrical current pulses are controlled by electronic switches it is not practicable to place the coil not being energised in open circuit since dangerous over voltages can be produced. In some instances, upon attempting manual operation of a two coil actuator whilst a current path exists in either coil, incorrect operation may occur.

CLAIMS

1. An electrical actuator including a plunger extending co-axially through an armature or pole piece associated with an electrical coil and a permanent magnet array axially adjacent to the electrical coil, the plunger having secured thereto a co-axial magnetisable plunger sleeve extending through the permanent magnet array and partially through the electrical coil with an end face registering with the armature and having biassing means arranged to urge the plunger axially away from the armature, first electric circuit means effective to energise the electrical coil to produce a magnetic flux augmenting a magnetic flux arising from the permanent magnet array and opposing the biassing means to effect axial movement of the plunger sleeve toward the armature, second electric circuit means effective to energise the electrical coil to produce a magnetic flux opposing the magnetic flux arising from the permanent magnet array and augmenting the biassing means to effect axial movement of the plunger sleeve away from the armature, and electrical switch means arranged selectively to connect the electrical coil to one of the first electric circuit means, the second electric circuit means and an open circuit.

2. An electrical actuator as claimed in Claim 1, wherein the permanent magnet array is in the form of flat rectangular cross-section block magnets.

3. An electrical actuator as claimed in Claim 1 or Claim 2, wherein the permanent magnet array is in the form of a stack of discs bolted together.

4. An electrical actuator as claimed in Claim 3,

wherein each of the discs has a thickness of approximately 7 millimetres.

5. An electrical actuator as claimed in any preceding Claim, wherein the permanent magnet array is composed of isotropic neodymium ferro boron material.

6. An electrical actuator as claimed in any preceding Claim, wherein the plunger sleeve is of parallelepiped external form.

7. An electrical actuator as claimed in any preceding Claim, wherein the end face of the plunger sleeve registering with the armature is of stepped form.

8. An electrical actuator as claimed in any preceding Claim, wherein the magnetic fluxes arising at the electrical coil, the armature, the plunger sleeve and the permanent magnet array are such that a relatively low reluctance path is offered to the magnetic flux in the magnetic circuit in a closed position of the actuator and an electrical tripping pulse current of down to approximately three amps is effective to overcome the magnetic flux retaining the actuator in the closed position and to cause movement of the actuator to an open position.

9. An electrical actuator as claimed in Claim 8, wherein the value of the electrical current pulse required to move the actuator to the open position is approximately one tenth of the value of the electric current pulse required to move the actuator to the closed position.

10. An electrical actuator arranged and adapted to operate substantially as hereinbefore described with reference to the accompanying drawing.

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Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
GB 9409139.4

Search Examiner
C D STONE

Relevant Technical Fields

(i) UK Cl (Ed.N) H1P (PBA, PMR)

(ii) Int Cl (Ed.6) H01F/7/16

Date of completion of Search
8 AUGUST 1995

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Documents considered relevant following a search in respect of Claims :-
ALL

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	US 4157520	(WESTINGHOUSE)	1 at least
X	US 4072918	(REGDON)	1 at least
X	US 4000481	(I.T.E)	1 at least
X	US 3886507	(WESTINGHOUSE)	1 at least
X	US 3792390	(ALLIS-CHALMERS)	1 at least
X	US 3091725	(AMERICAN RADIATOR)	1 at least

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